cef.up
Centro de Economia e Finanças da UPorto

CEF.UP Working Paper 2011-05

SYNCHRONIZATION OF ECONOMIC SENTIMENT CYCLES IN THE EURO AREA: A TIME-FREQUENCY ANALYSIS

Luís Aguiar-Conraria
Manuel M. F. Martins
Maria Joana Soares

Centro de Economia e Finanças da UP
www.fep.up.pt

Synchronization of Economic Sentiment Cycles in the Euro Area: a time-frequency analysis

Luís Aguiar-Conraria
lfaguiar@eeg.uminho.pt
Universidade do Minho, NIPE [†] and Escola de Economia e Gestão,

Manuel M. F. Martins[*]
mmfmartins@fep.up.pt
Universidade do Porto, Cef.up [‡] and Faculdade de Economia,

Maria Joana Soares
jsoares@math.uminho.pt
Universidade do Minho, NIPE [†] and Departmento de Matemática,

15 September 2011

Abstract

We use wavelet tools and Economic Sentiment Indicators to study the synchronization of economic cycles in the Euro Area. We assess the time-varying and frequency-varying pattern of business cycles synchronization in the Area and test the impact of the creation of the European Monetary Union in 1999.

Among several results, we find that (a) the EMU is associated with a significant increase in synchronization of economic sentiment in the Euro Area; (b) the hard-peg of its currency to the Euro led to a comparable synchronization of Denmark's economic sentiment after 1999, differently from what happened in the case of the UK.

Keywords: Business cycle synchronization; Economic sentiment; Euro Area; Continuous wavelet transform; Wavelet coherency; Wavelet distance; Phase-difference.

JEL Classification Numbers: C32, C49, E32, F44.

---

[*] Authors in alphabetical order. Corresponding author.

[†] NIPE – Núcleo de Investigação em Políticas Económicas – is supported by the Fundação para a Ciência e a Tecnologia (FCT), Portugal.

[‡] Cef.up – Centre for Economics and Finance at the University of Porto – is supported by the Fundação para a Ciência e a Tecnologia (FCT), Portugal.

1. Introduction

The assessment of the synchronization of business cycles in the Euro Area has received a lot of attention in the recent literature but remains largely an open issue (see e.g. Altavilla, 2004; Artis, Krolzig, and Toro, 2004; De Haan, Inklaar and Jong-a-Pin, 2008; Camacho, Perez-Quirós and Saiz, 2008; Furceri and Karras, 2008; Canova, Ciccarelli, and Ortega, 2009 and Giannone, Lenza and Reichlin, 2009).

The relevance of the subject is twofold. At a normative level, it is one of the crucial issues for analysing the sustainability of the European Monetary Union (EMU), as the synchronization of the cyclical oscillations in real economic activity is necessary for the optimality of a single monetary policy. At a positive level, it is a case-study to test the hypothesis of the endogeneity of optimum currency areas, as a proper comparison of the synchronization before and after the creation of the EMU in 1999 may shed light on the effects of the new regime.

The lack of consensual results in the literature often arises from the use of alternative concepts of the business cycle (deviation, classical and growth cycles — see Artis, Marcellino and Proietti, 2004). Yet, it also occurs in studies that adopt the same approach to measure the business cycle, but differ in the specific econometric methods used, say for de-trending/filtering the data or for modelling the business cycle oscillations. Moreover, even within the same concept of the business cycle and econometric technique, disparate results often arise from different data — the specific time-series representing real economic activity and/or the sample period. Overall, the review of the literature suggests that the discrepancy in results may be related to time-varying patterns of synchronization (see e.g. Koopman and Azevedo, 2008) and that such time-variation may, moreover, differ across frequencies of oscillation (see Hallett and Richter, 2006 and 2008). Hence the motivation for using a method that simultaneously considers time and frequency, allowing for the assessment of synchronization with possible time-variation in its intensity and in its lead-lags, explicitly considering the various frequencies of cyclical oscillations.

Against this background, this paper fills a gap in the literature, providing evidence from a new combination of data and method: the assessment of the pattern of business cycle synchronization in the time-frequency domain with wavelet tools, using data from the Economic Sentiment Indicators (ESIs).

The ESIs have at least been used once to study synchronization of business cycles in the Euro Area (see Gayer, 2007), given their highly appealing feature of mimicking the growth rate of real GDP at a monthly frequency (on the construction and properties of the ESI see e.g. Gelper and Croux, 2010). However, this analysis was conducted in the time domain. Thus, the advantages of time-frequency approaches to the assessment of the synchronization of business cycles have not yet been explored with this valuable data-set.

So far, the analyses of the synchronization of business cycles in the Euro Area that have explored time-frequency techniques have looked either at quarterly data — namely real GDP (Crowley, Maraun and Mayes, 2006; Hallett and Richter, 2008, 2006, 2004b; Wozniak and Paczynski, 2007; and Rua, 2010) — or at monthly data that account only for a part of overall economic activity — namely industrial production (Aguiar-Conraria and Soares, 2011a).

In this paper, we uncover the time-varying patterns of the synchronization of business cycles in the Euro Area at various frequencies, with data that are rich in the double sense that it effectively proxies for the growth rate of real GDP — i.e. aggregate real economic activity — and is available monthly since the mid-1980s. In particular, the (monthly) periodicity and length (about 12 years before and 12 years after the creation of the EMU) of our data, allows for the use of sophisticated and data-consuming econometric techniques as well as for the study of balanced sub-samples corresponding to a period before and a period after the EMU.

We use the continuous wavelet transform, which only recently has received attention in Economics (see e.g. Aguiar-Conraria, Soares, and Azevedo, 2008). Specifically, we estimate the wavelet power spectrum of each ESI time-series, and then compute the wavelet coherency and phase difference between each country's ESI and the aggregate Euro Area's ESI, thus assessing the co-movement of economic sentiments along time at all frequencies, as well as their leads and lags. We also compute a wavelet distance matrix and test whether synchronization between the ESIs of all pairs of countries and of each country and the Euro Area is statistically significant. To look more precisely at the impact of EMU, we split the sample at 1999, and compute a wavelet distance matrix for both the pre-EMU and the post-EMU period.

Given the availability of data, we consider a Euro-10 aggregate Euro Area, comprised of the 11 founding-members, except Luxembourg and Finland, plus Greece. As controls, we also consider the economic sentiments of the UK and Denmark: the former allows for checking whether an exchange-rate floating regime has led to a different performance as regards synchronization of economic sentiment; the latter, allows for assessing whether a hard-peg to the Euro has had different effects on the co-movement of economic sentiment in comparison with the formal participation in the EMU.

The remainder of this paper is structured as follows. Section 2 presents the data. Section 3 explains the wavelet methods. Section 4 shows and discusses the empirical results. Section 5 offers some concluding remarks.

2. Data

Data are monthly time-series of the Economic Sentiment Indicators (ESIs) published online by the Eurostat.[1]

Each ESI is a weighted average of five confidence indicators (CIs) computed from national surveys — the industrial CI (weighting 40 per cent), the services CI (30 per cent), the consumer CI (20 per cent), the retail trade CI (5 per cent) and the construction CI (5 per cent). To guarantee comparability across countries, the European Commission has implemented a programme of harmonization of the national surveys; moreover, all CIs are standardized for an average of 100 and a standard deviation of 10 (for further details on the construction of the ESIs, see European Commission, 2007). The resulting time-series of ESIs mimic quite closely the year-on-year growth rate of real GDP, as can be seen in Figure 1 for the aggregate Euro Area.

In what regards the EMU, in this paper we consider data from 10 Euro Area members — the 11 founding-members of the EMU, except Luxembourg and Finland, plus Greece: i.e. Austria, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. Out of the current 17 EMU members, we excluded Cyprus, Luxembourg, Finland, Malta, Estonia, Slovenia and Slovakia because their ESI time-series are either too short or include only a very limited part of the 5 survey-based confidence indicators during a large part of the sample, so that the available time-series preclude a meaningful econometric analysis.

[1] Available at http://ec.europa.eu/economy_finance/db_indicators/surveys/time_series/index_en.htm (accessed March 2011).

Throughout 1985-2010, the aggregate real GDPs of the 10 members of the Euro Area that we use as reference represents about 97 per cent of the aggregate real GDP of the 17 countries that currently make up the Euro Area. Hence, our aggregate Euro-10 Area may be comfortably seen as a very good proxy for the whole Euro Area.

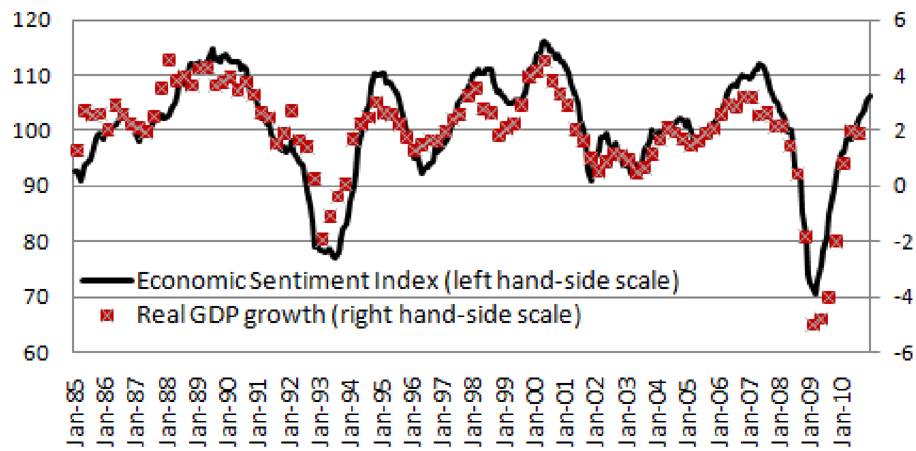

Figure 1: Economic Sentiment Index vs GDP growth, Euro Area 1985:1-2010:12

Furthermore, we consider two non-EMU countries, for which there is a satisfactory amount of data and may be used as controls, in that one has had a de facto hard-peg to the euro — Denmark — while the other has had a floating exchange rate against the euro — the United Kingdom.[2]

For most of the countries the ESI data begin in 1985:1, but we focus on the sample period 1987:4-2010:12 because data for Portugal and Spain begin only in 1987:1 and 1987:4, respectively.

In the case of Ireland, the publication of confidence indicators and of the ESI by the European Commission services has been discontinued since 2008:5, due to the unavailability of such official data. To fill the gap, we use the Consumer Sentiment Index (CSI) computed and published jointly by the Economic and Social Research Institute (ESRI) and the KBC Bank Ireland.[3]

---

[2] While in principle a good candidate for this control group (paralleling the UK), Sweden has not been considered because its ESI is entirely based on the building sector survey until 1995:12 and includes values for the whole 5 surveys only since 1996:8.

[3] Available at http://www.esri.ie/irish_economy/consumer_sentiment/ (accessed March 2011). We thank Comarc O'Sullivan from ESRI for providing the historic time-series of the CSI, for 1996:2-2010:12. The CSI has a correlation of 84 per cent with the ESI in the overlapping sample (1996:2—2008:4), which makes it a strong proxy for the ESI. After due standardization for an average of 100 and a standard

We have computed the aggregate Euro Area ESI for our 10 member states Euro Area (EA-10) from the individual countries' ESIs, using as weights the share of each country in the aggregate EA-10 real GDP. For consistency with the sources of the European Commission, we have used real GDP data from the AMECO database, except for Germany 1985-1990, where we have used a OECD real GDP time series (with a consistent base year) that includes estimates for Eastern Germany GDP. For the sample period we focus on, the resulting EA-10 ESI has a correlation of 99.7 percent with the Euro Area ESI computed by the European Commission, has an identical average (100.9) and a quite close standard deviation (8.7 *vs* 9.7). We thus concluded that our method is adequate and so proceeded with our approach to compute all the aggregate ESIs needed for our empirical analyses.

Assessing the synchronization of the economic sentiment in the UK and Denmark, on the one hand, and the Euro Area, on the other hand, involves those countries' ESIs and the EA-10 ESI. Assessing the synchronization between each of the 10 member-states and the Euro Area, differently, requires the computation of the ESI for a notional Euro Area that excludes each country in turn, as we are interested in checking the co-movement of each country's economic sentiment and the rest of the EA-10. Accordingly, we used the described method to compute ten time-series of EA-9 ESIs.

3. Wavelets

Wavelet analysis performs the estimation of the spectral characteristics of a time-series as a function of time, revealing how the different periodic components of a particular time-series evolve over time. While in spectral analysis we break down a time-series into sines and cosines of different frequencies and infinite duration in time, the wavelet transform expands the time-series into shifted and scaled versions of a function that has limited spectral band and limited duration in time. In spite of its theoretical soundness, this technique is still rarely used in the Economics and Political Science literature. The technically inclined reader is referred to Aguiar-Conraria and Soares (2011b), who offer a detailed description on the mathematics of wavelets.[4]

deviation of 10 (for comparability with the ESI), we have used these data as a proxy for Ireland's ESI for 2008:5—2010:12

[4] The technical details related to wavelet analysis are thoroughly explained in this paper. Associated with that paper, there is Matlab wavelet toolbox, freely available at http://sites.google.com/site/aguiarconraria/joanasoares-wavelets.

For a detailed intuitive explanation, we refer the reader to Aguiar-Conraria, Magalhães and Soares (2011).

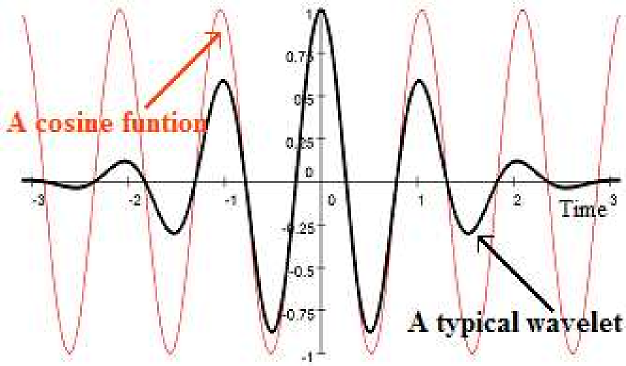

Figure 2: The typical wavelet function versus a cosine function. While the cosine function alway ranges between -1 to 1, the wavelet function approaches zero when it moves away from the center

Apart from some technical details, for a function to qualify for being a wavelet — Figure 2 —, it must have zero mean (implying that it has to wiggle up and down) and be well-localized in time (e.g. have compact support or, at least, fast decay), behaving like a small wave that loses its strength as it moves away from the centre, hence the term choice wavelet. It is this property that allows, contrary to the Fourier transform, for an effective localization in both time and frequency.

Complex analytic wavelets are ideal to study oscillations. We use the most popular wavelet with these characteristics, the Morlet wavelet.[5]

Given a time series $x(t)$, its continuous wavelet transform (CWT) with respect to the wavelet is a function of two variables, $W_x(\tau, s)$:

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \bar{\varphi}\left(\frac{t-\tau}{s}\right) dt,$$

where the bar denotes complex conjugation, s is a scaling or dilation factor that controls the width of the wavelet and τ is a translation parameter controlling the location of the wavelet. With our wavelet choice, there is an inverse relation between wavelet scales and frequencies, $f \approx 1/s$, greatly simplifying the interpretation of the empirical results.

In analogy with the terminology used in the Fourier case, the (local) wavelet power spectrum is defined as

$$WPS_x(\tau, s) = |W_x(\tau, s)|^2.$$

[5] The reader is referred to Aguiar-Conraria and Soares (2011b) for technicalities about the optimal properties of such wavelet.

This gives us a measure of the variance distribution of the time-series in the time-scale/frequency plane. To see how this works, check Figure 3, which shows the wavelet power spectrum of a time-series with a 4 year cycle in the first half of the sample, which is replaced by a 6 year cycle in the second half.

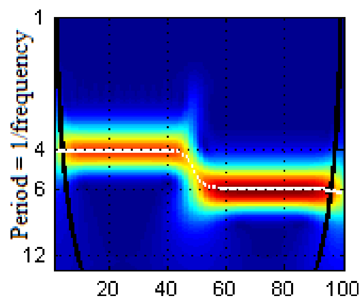

Figure 3: The wavelet power spectrum

Our wavelet figures throughout the paper depict the power at each time-frequency region associating colder colours (in the extreme, blue) with low power and hotter colours (in the extreme, red) with higher power. The white lines show the maxima of the undulations of the wavelet power spectrum, therefore giving a direct estimate of the cycle period. The region outside the thick black lines is called the cone of influence (COI).[6]

For convenience, in the vertical axis of the spectrum — as in all other time-frequency charts throughout the paper — we have converted frequencies into cyclical periods in years. The wavelet power spectrum density depicted in the picture tells us that 4 and 6-year cycles are important to explain the total variance of the time-series, respectively, in the first and second halves of the sample.

The concepts of cross wavelet power, wavelet coherency and phase-difference are natural generalizations of the basic wavelet analysis tools, which enable us to deal with the time-frequency dependencies between two time-series. The cross-wavelet transform of two time-series, $x(t)$ and $y(t)$, is defined as $W_{xy}(\tau,s) = W_x(\tau,s)\bar{W}_y(\tau,s)$. The cross-wavelet power of two time-series, $|W_x(\tau,s)|$, depicts the local covariance between two time-series at each time and frequency. When compared with the cross wavelet power, the wavelet coherency has the advantage of being normalized by the power spectrum of the two time-series. In analogy with the concept of coherency used in

[6] In the COI, the results have to be interpreted carefully. In particular, given the algorithm we use, the wavelet power in the beginning and the end of the time-series will tend to be underestimated.

Fourier analysis, given two time-series $x(t)$ and $y(t)$, one defines their wavelet coherency:

$$R_{xy}(\tau,s)=\frac{\left|S\left(W_{xy}(\tau,s)\right)\right|}{\sqrt{\left|S(W_{xx}(\tau,s))S\left(W_{yy}(\tau,s)\right)\right|}},$$

where *S* denotes a smoothing operator in both time and scale.

One of the major advantages of using a complex-valued wavelet is that we can compute the phase of the wavelet transform of each series and thus obtain information about the possible delays of the oscillations of the two series as a function of time and frequency, by computing the phases and the phase difference. The phase is given by $\tan^{-1}\left(\Im\left(W_x(\tau,s)\right)/\Re\left(W_x(\tau,s)\right)\right)$ and the phase difference by $\tan^{-1}\left(\Im\left(W_{xy}(\tau,s)\right)/\Re\left(W_{xy}(\tau,s)\right)\right)$, where, for a given complex number *z*, $\Re(z)$ and $\Im(z)$ denote, respectively, its real part and imaginary part. A phase-difference of zero indicates that the time series move together at the specified frequency; a phase-difference between 0 and $\pi/2$ indicates that the series move in phase, with *x* leading *y*, while if the phase-difference is between 0 and $-\pi/2$, then it is *y* that is leading; see Figure 7 for the other cases.

In addition to wavelet power spectra, wavelet coherency and phase-differences, we use the measure of the dissimilarities between wavelet spectra of two time-series, say $x(t)$ and $y(t)$, proposed by Aguiar-Conraria and Soares (2011a), which we now describe. We use the Singular Value Decomposition (SVD) of a matrix to focus on the common high power time-frequency regions. Because this method extracts the components that maximize covariances, the first extracted components correspond to the most important common patterns between the wavelet spectra. With those, we construct leading patterns and leading vectors. Using just a few of these, say *K*, one can approximately reconstruct the original spectral matrices, guaranteeing that the fraction of covariance is above 90%.

Then, to define a distance between the two spectra, we measure the distances from these components. As Aguiar-Conraria and Soares (2011a), to compare the wavelet spectra of countries x and y, we compute the following distance:

$$\mathrm{dist}\left(W_x,W_y\right)=\frac{\sum_{k=1}^{K}\sigma_k^2\left[d\left(\mathbf{l}_x^k,\mathbf{l}_y^k\right)+d\left(\mathbf{u}_x^k,\mathbf{u}_y^k\right)\right]}{\sum_{k=1}^{K}\sigma_k^2} \qquad (1)$$

In the above formula, $\mathbf{l}_x^k$ and $\mathbf{l}_y^k$ are the leading patterns, $\mathbf{u}_x^k$ and $\mathbf{u}_y^k$ the singular vectors and σ_k the singular values. We compute the distance between two vectors by measuring the angle between each pair of corresponding segments, defined by the consecutive points of the two vectors, and take the mean of these values.

The above distance is computed for each pair of countries and, with this information, we can then fill a matrix of distances. The closer to zero our measure of distance is, the more similar are the wavelet transforms of $x(t)$ and $y(t)$.

4. Results: how far apart are the Euro countries

For a first glance at the data, in Figure 4 we show the EA-10 ESI time series and its wavelet power spectrum (the variance of the series at each time-frequency locus). Because we want to focus our analysis on business cycle frequencies, we remove short-run noise using a wavelet-based filter and we estimate the wavelet power spectra between 1.5 and 8 years frequencies. The interpretation of the wavelet power spectrum is similar to the one provided for Figure 3. However, in this case, we also added information on the statistical significance of the power spectrum. The dark lines represent regions of statistically significant powers at 5 per cent.[7]

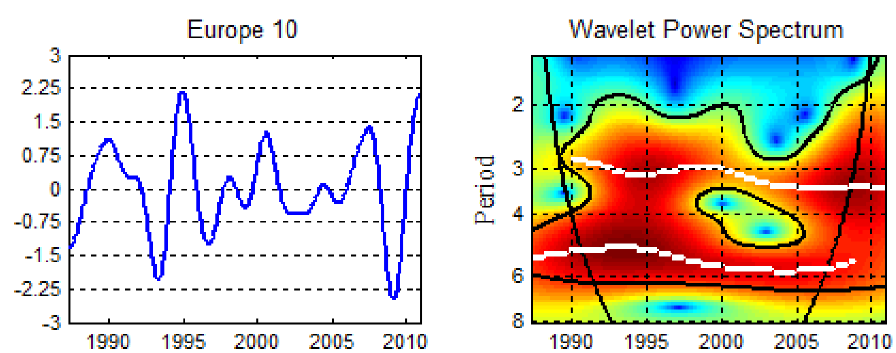

Figure 4: EA-10 Economic Sentiment Index 1987:4-2010:12

The left-hand side chart shows that, in the EA-10, economic sentiment has fluctuated less from 1997 to 2007 than in the beginning and in the final part of the sample period (the well-known 1993 recession and 2008 financial and economic crisis, respectively). The 1997-2007 low-volatility era appears in the right-hand side chart as a reduction of

[7] Throughout the paper, to perform significance tests of wavelet measures we use the following procedure. We fit an ARMA (1,1) model and construct new samples by drawing errors from a Gaussian distribution with a variance equal to that of the estimated error terms. For each time-series (or pair of time-series) we perform the exercise 5000 times, compute the quantity of interest (in this case the wavelet power spectrum) for each generated sample, and then extract the critical values.

the area of significant variance during that period, clearly seen in the hole for cycles of period between 3.5 and 5 years, and also somewhat in the loss of significance of the spectrum for cycles of period between 2 and 3 years in the early 2000s.

The sharp fluctuations of the ESI in the early 1990s and in the end of the 2000s show up in the wavelet power spectrum very clearly, as sizeable peaks of energy. In the first episode, those peaks occur at cycles with a period of 3 years (around 1995) as well as at cycles with a period of 5 years (extensively between 1992 and 1997). In the second episode they look somehow more concentrated in cycles of a 3 year period, but one should not over-emphasize the reading of these results as the spectrum is under the cone of influence since 2007 for cycles with longer duration.

The wavelet spectrum detects very clearly (which the time-domain chart does not) that the fluctuations of the EA-10 ESI series develop along two strong cycles throughout most of the sample. In fact, the white stripes in the spectrum indicate that there are two maxima of power, one corresponding to cycles with a period around 3 years and the other two cycles with a period slightly below 6 years; furthermore, they indicate that the smaller cycles have become slightly longer during the early 2000s, to a period around 3.5 years; and that the larger cycles had in fact a 5 years period until 1995, then changing to a longer cycle until settling at a 6 years period cycle since 2000. For the sake of saving space, we do not present the wavelet power spectra of the individual countries.[8]

For most of the countries, their overall pattern is close to that of the EA-10 spectrum depicted in Figure 4, and discussing the differences would require a very cumbersome description of details. The power spectra that differ the most from that of the EA-10 are those of Greece, the Netherlands, Portugal, Denmark and the UK. In the case of Greece, the two main cycles present in Figure 4 are only significant in the second half of the sample, which is especially clear for the shorter one. In the case of Portugal, the 6 year cycle is clear only after 2000, following a period between 1995 and 2000 when a 5 years cycle became significant and gradually became longer. In the United Kingdom the 3 year cycle only appears after 1995 and the 6 year cycle seems to become shorter and to vanish after 2007. In Denmark, the 3 year cycle appears only after 1990 and the 6 years cycle only since 1995; moreover, at the end of the sample period, as the shorter

[8] These, as all data and codes needed to replicate our results, are available at http://sites.google.com/site/aguiarconraria/joanasoares-wavelets.

cycle became longer and the longer one became shorter, they seemed to be converging to a single 4 year cycle. The Netherlands is the only country in which the 3 year cycle seemingly disappears in the beginning of the 2000s, to reappear again after 2005.

4.1. Wavelet distances

In this subsection we perform a first step in the assessment of the co-movement between the ESIs of the 12 European countries in our sample as well as between each country and the aggregate EA-10 (duly excluding the country, if a member of the EMU). Based on formula (1), we compute a measure of distance between the wavelet transform of each ESI series that takes into account both their real and imaginary part. The closer the distance is to zero, the more the ESI series share their high power regions with their phases aligned. This means that (i) the contribution of cycles at each frequency to the total variance is similar, (ii) this contribution happens at the same time and, finally, (iii) the ups and downs of each cycle occur simultaneously. In this sense, we say that a value close to zero between two variables means that their cycles are highly synchronized.

Table 1: Wavelet distances (full sample)

	Be	Ge	Ir	Gr	Sp	Fr	it	Ne	Au	Pt	Dk	UK
Belgium		0.14	0.19	0.37	0.21	0.13	0.23	0.19	0.14	0.27	0.24	0.38
Germany	0.14		0.20	0.41	0.21	0.16	0.26	0.27	0.17	0.29	0.35	0.43
Ireland	0.19	0.20		0.36	0.26	0.15	0.18	0.24	0.27	0.36	0.34	0.43
Greece	0.37	0.41	0.36		0.44	0.34	0.34	0.33	0.41	0.52	0.43	0.34
Spain	0.21	0.21	0.26	0.44		0.22	0.22	0.25	0.18	0.33	0.29	0.47
France	0.13	0.16	0.15	0.34	0.22		0.16	0.23	0.17	0.35	0.27	0.40
Italy	0.23	0.26	0.18	0.34	0.22	0.16		0.21	0.26	0.45	0.30	0.35
Netherlands	0.19	0.27	0.24	0.33	0.25	0.23	0.21		0.25	0.36	0.24	0.34
Austria	0.14	0.17	0.27	0.41	0.18	0.17	0.26	0.25		0.30	0.32	0.40
Portugal	0.27	0.29	0.36	0.52	0.33	0.35	0.45	0.36	0.30		0.31	0.36
Denmark	0.24	0.35	0.34	0.43	0.29	0.27	0.30	0.24	0.32	0.31		0.38
United Kingdom	0.38	0.43	0.43	0.34	0.47	0.40	0.35	0.34	0.40	0.36	0.38	
Europe 10	0.11	0.18	0.16	0.36	0.16	0.11	0.19	0.22	0.15	0.32	0.27	0.42
							p<0.01		p<0.05		p<0.10	

We first present a distance matrix computed for the whole sample, in Table 1. A first conclusion is that the ESIs of Greece and the UK are the least synchronized with those of the other European countries, and these countries record no significant bilateral distance even at the 10 percent level. While that could be expected for the case of the UK — an EU member that opted out of the EMU in part because of diachronic business cycles — it confirms the conventional wisdom that the inclusion of Greece in the EMU has been somehow questionable, as regards cyclical convergence. A second conclusion is that the ESI of Portugal is also rather distant from most countries' ESIs, when their co-movements are assessed in the time-frequency domain. As the table is further tracked for low levels of synchronization of ESIs, Denmark shows up next: it has only 3 bilateral distances low enough to be significant at the 5 per cent level.

In the last row of Table 1 we present the distance between the wavelet transform of each country's ESI and that of the aggregate EA-10 ESI (with exclusion of the country if a member of the EMU). The distances are small enough to infer that there is synchronization at the 1 per cent level for Belgium, Germany, Ireland, Spain, France, Italy and Austria. The Netherlands may yet be included in this core of countries, as its ESI is synchronized with the EA-10 in the time-frequency domain at the 5 per cent level. Among the countries that adhered to the EMU, only Portugal and Greece have ESIs that fail to synchronize with the EA-10 even at 10 per cent of significance. Of the two control countries, the one that has had its currency hard-pegged to the Euro (Denmark) is synchronized at the 10 per cent, while the one that has had its currency floating (the UK) is not statistically synchronized with the EA-10.

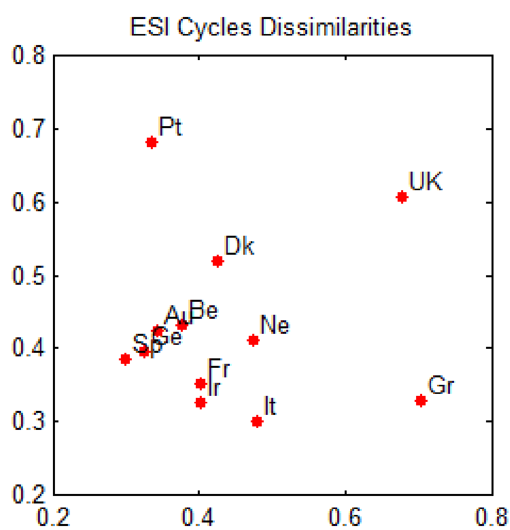

Figure 5: Multidimensional scaling map (full sample)

To provide a more intuitive reading of Table 1, in Figure 5 we follow Camacho, Perez-Quirós and Saiz (2006) and summarize the distances in a two-dimensional map. In short, the distance matrix is reduced to a two-column matrix that positions each country in two orthogonal axes, and then each country is accordingly placed on a plane.

Figure 5 confirms that when time and frequency are considered together, the ESIs of Portugal, Greece and the UK record a low co-movement with the ESIs of the remaining European countries here considered. The figure also confirms that economic sentiment in Denmark has co-moved weakly with economic sentiment in the other European countries. The figure further informs that there has been a core of countries as regards economic sentiment fluctuations formed by Germany, Austria, Belgium, Spain, the Netherlands, France, Ireland and Italy. This core may, however, be divided into two sub-groups, one centred around Germany (including Austria, Belgium and Spain) and the other more concentrated around France (including Ireland and Italy), while the Netherlands seems to be in the middle of these sub-groups.

We now split the sample in two sub-samples of the same size, the first almost exactly corresponding to the period before the creation of the EMU (1987:04-1999:02) and the second almost exactly corresponding to the period after the beginning of the EMU (1999:02-2010:12). We compute the wavelet distances for each period and check whether the results indicate any effect of the EMU on the synchronization of economic sentiment across Europe.[9]

The comparison between panel A (pre-Euro period) and panel B (post-Euro period) of Table 2 is striking. It indicates that the creation of the EMU in 1999 led to a fall in the distance between the wavelet transform of the national ESIs and of the EA-10 ESI for all countries, except Spain, France and Austria, where it remained very low and kept on suggesting synchronization at 1 per cent (5 per cent in the case of Spain). That fall was not uniform and changed the overall picture. Before the EMU, only the ESIs of Belgium, Germany, France and Austria were synchronized at 1 per cent of significance and those of Ireland, Spain and Italy were synchronized at the 5 per cent level. Greece, Portugal and the Netherlands were not synchronized with the rest of Europe. The same lack of synchronization occurred, as expected, for the non-members Denmark and the UK.

After the EMU, the ESIs of all the members of the EA-10 became synchronized with the aggregate EA-10 ESI in the time-frequency domain at least at the 5 per cent level (remaining significant at the 1 per cent level of significance for Belgium, Germany, France, and Austria, which emerges clearly as the hard core of the EA-10). There has

[9] It is important that the sample is split exactly in half, so that the COI distortions affect both sides exactly in the same way avoiding possible biases in the results.

also been a convergence of co-movements with the EA-10 by Denmark. The other control country, the UK, kept an asynchronous cycle with the Euro 10 area. Hence, we conclude that (i) participation in the EMU overall led to high levels of synchronization of the national ESIs with the EA-10 ESI, and (ii) hard-pegging the national currency to the Euro led Denmark to a comparable synchronization, not seen in the case of the UK given its floating exchange regime.

Table 2: Wavelet distances before and after the Euro

	Be	Ge	Ir	Gr	Sp	Fr	It	Ne	Au	Pt	Dk	UK
Belgium		0.12	0.16	0.36	0.13	0.11	0.17	0.19	0.09	0.30	0.25	0.33
Germany	0.12		0.19	0.40	0.17	0.11	0.19	0.27	0.09	0.33	0.39	0.35
Ireland	0.16	0.19		0.33	0.21	0.14	0.15	0.21	0.20	0.36	0.34	0.27
Greece	0.36	0.40	0.33		0.36	0.41	0.39	0.21	0.43	0.46	0.45	0.30
Spain	0.13	0.17	0.21	0.36		0.17	0.16	0.22	0.15	0.27	0.22	0.30
France	0.11	0.11	0.14	0.41	0.17		0.11	0.27	0.11	0.36	0.33	0.34
Italy	0.17	0.19	0.15	0.39	0.16	0.11		0.27	0.20	0.34	0.31	0.27
Netherlands	0.19	0.27	0.21	0.21	0.22	0.27	0.27		0.26	0.35	0.25	0.27
Austria	0.09	0.09	0.20	0.43	0.15	0.11	0.20	0.26		0.28	0.35	0.36
Portugal	0.30	0.33	0.36	0.46	0.27	0.36	0.34	0.35	0.28		0.26	0.48
Denmark	0.25	0.39	0.34	0.45	0.22	0.33	0.31	0.25	0.35	0.26		0.32
United Kingdom	0.33	0.35	0.27	0.30	0.30	0.34	0.27	0.27	0.36	0.48	0.32	
Europe 10	0.09	0.12	0.15	0.39	0.14	0.07	0.15	0.25	0.10	0.31	0.30	0.33
A. FIRST HALF OF THE SAMPLE (PRE-EURO)							p<0.01		p<0.05		p<0.10	

	Be	Ge	Ir	Gr	Sp	Fr	It	Ne	Au	Pt	Dk	UK
Belgium		0.09	0.15	0.15	0.19	0.09	0.15	0.16	0.13	0.17	0.18	0.16
Germany	0.09		0.14	0.14	0.16	0.10	0.14	0.17	0.12	0.14	0.20	0.22
Ireland	0.15	0.14		0.14	0.25	0.10	0.17	0.18	0.23	0.16	0.21	0.33
Greece	0.15	0.14	0.14		0.26	0.15	0.21	0.17	0.21	0.19	0.25	0.29
Spain	0.19	0.16	0.25	0.26		0.19	0.15	0.21	0.13	0.24	0.26	0.28
France	0.09	0.10	0.10	0.15	0.19		0.14	0.19	0.17	0.16	0.16	0.22
Italy	0.15	0.14	0.17	0.21	0.15	0.14		0.13	0.17	0.23	0.15	0.27
Netherlands	0.16	0.17	0.18	0.17	0.21	0.19	0.13		0.20	0.21	0.16	0.23
Austria	0.13	0.12	0.23	0.21	0.13	0.17	0.17	0.20		0.24	0.27	0.23
Portugal	0.17	0.14	0.16	0.19	0.24	0.16	0.23	0.21	0.24		0.26	0.16
Denmark	0.18	0.20	0.21	0.25	0.26	0.16	0.15	0.16	0.27	0.26		0.22
United Kingdom	0.16	0.22	0.33	0.29	0.28	0.22	0.27	0.23	0.23	0.16	0.22	
Europe 10	0.07	0.07	0.13	0.14	0.15	0.11	0.12	0.15	0.12	0.16	0.16	0.20
B. SECOND HALF OF THE SAMPLE (POST EURO)							p<0.01		p<0.05		p<0.10	

When bilateral distances are analysed, Panel A and Panel B give markedly different dynamics of the co-movement of economic sentiment within the EA-10. In 1987-1999 only 13 out of the 45 bilateral distances are small enough for synchronization to be significant at least at the 5 per cent level; in 1999-2010 there are 28 distances out of the

45 EA-10 bilateral distances significant at the 5 per cent level. Until 1999 there are 25 bilateral distances not significant at 10 per cent, while after 1999 there are only 9 such cases. These, after 1999, all involve Portugal, Spain, Ireland and Greece — and largely the lack of synchronization among them —, the first two recording 4 not significant bilateral synchronizations and the last two recording 2 bilateral not significant synchronizations. The mean distance among the Euro 10 countries drops from 0.24 to 0.17, a drop of almost 30%. Performing a t-test, one rejects the null of equal means with a p-value that is virtually zero.

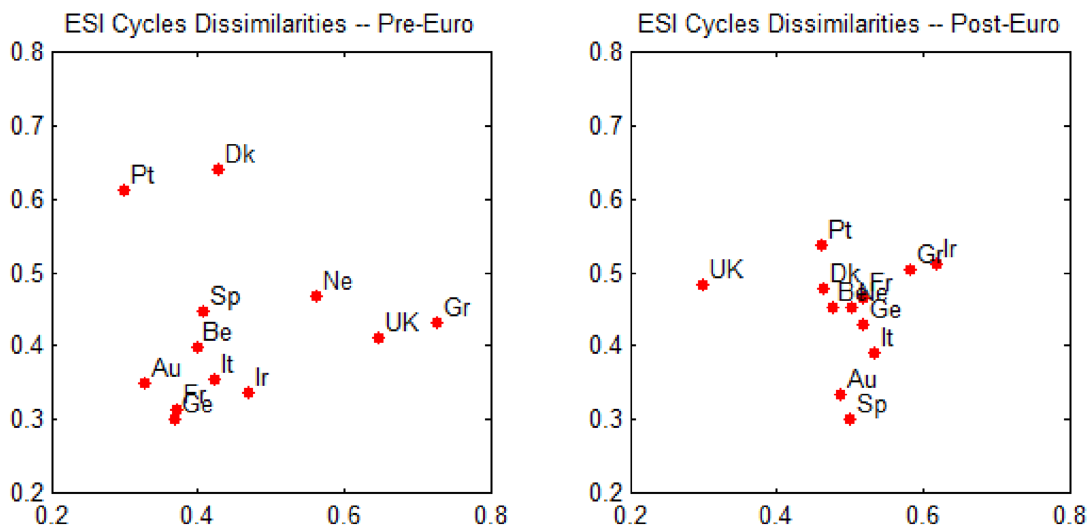

Figure 6: Multidimensional scaling maps for partial samples

As regards the control countries, a first interesting conclusion is that there is no significant synchronization between economic sentiment in Denmark and in the UK, not even after 1999. In the Euro period, in turn, the ESI of Denmark became significantly synchronized with those of France, Italy and the Netherlands and, albeit only at 10 per cent, with those of Belgium and Germany. As expected given the distances to the EA-10 described above, the ESI of the UK is only synchronized significantly with two small countries. These results reinforce the conclusion that the hard-peg of its currency to the Euro led to a significant convergence of Denmark's economic sentiment to the EA-10 core countries' economic sentiment, which the UK did not record.

Figure 6 offers a more intuitive reading of Table 2, summarizing the distances in two multidimensional scaling maps for the two sub-samples. Clearly, the UK is the only country that has not become more in sync with the rest of Europe and Denmark is not visibly distant from core countries such as France and Belgium and is even closer to the nucleus than Portugal, Ireland and Greece.

Hence our conclusions that, when time and frequency are considered jointly, (i) the EMU led, overall, to a significant convergence of economic sentiment in the EA-10, and (ii) the hard-peg of the Danish Krown to the Euro led to a comparable convergence, that did not happen in the case of the UK, given the floating regime of the British Pound, which may have immunized the UK against fluctuations in the Euro area.

4.2. Wavelet coherencies and phase-differences

In this section, we carry out a second step in the assessment of the synchronization between the ESIs, estimating the wavelet coherencies and phase-differences for all pairs formed by each individual country and the aggregate 10-country Euro Area (with exclusion of the country, if member of the EMU). The main advantage of these analyses is that cross-wavelets and phase-differences allow for assessing the evolution of the co-movement in the time-frequency domain continuously along the sample period, for all relevant cycles, as well as for establishing the lead-lag relations between each ESIs. Given our focus on business cycles (1.5~8 years period), and given that we found in the wavelet power spectra a marked concentration of energy at 2 cycles — one of period 3~3.5 years and the other of period 5~6 years —, we split the phase-differences in two charts, one for cycles in the frequency band of 1.5~4.5 years and other for cycles in the frequency band of 4.5~8 years. In Figure 8 we show, for each pair formed by a country and the EA-10, the wavelet coherency and, at its right, the phase differences (in Figure 7 we provide the key to interpret the phase-differences).

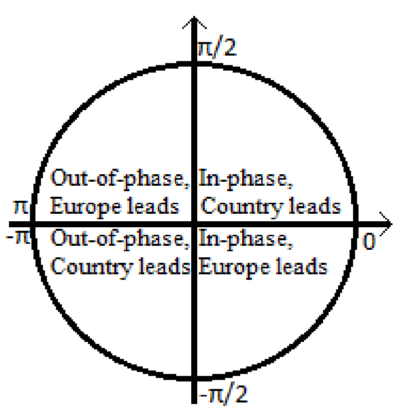

Figure 7: Unit circle and interpretation of Phase-differences

A first global conclusion from Figure 8 is that there are no significant episodes of inverse co-movements of any ESIs. In fact, in all episodes of significant coherencies the phase-differences are located between $-\pi/2$ and $\pi/2$, indicating that the ESIs are in-phase, i.e. they co-move positively.

A second global conclusion is that after 2005 all countries have large time-frequency regions — corresponding to cycles of various periods — in which there is a significant coherency between their ESIs and the EA-10 ESI. Truly, much of those regions are outside the cone of influence; anyway, this result, even if valid, seems associated not with any effect of the EMU but with the recent financial and economic boom and bust.

A third level of indications to be drawn from Figure 8 relates to the overall analysis of the coherency between the national ESIs and the EA-10 ESI. Consistently with the findings of the previous section, the countries with larger regions of significant coherency of their ESIs with the EA-10 ESI throughout the whole sample are Austria, Belgium, Germany and France; these may be thought of as the hard core of the EA-10, as they had their ESIs synchronized at 1 per cent already before 1999.

The wavelet coherencies then suggest that the Netherlands, Spain and Italy also record extended areas of significant coherency. These countries, most especially the Netherlands, exhibit a more pronounced hole in coherency at the end of the 1990s and the first half of the 2000s. This may explain why the Netherlands recorded so badly as regards synchronization, in the analysis of the previous section, before 1999.

Next, the figure shows that the ESI of Ireland has had a consistently significant coherency with the EA-10 ESI for cycles of period above 5 years throughout the whole sample (while coherency at shorter cycles is much more scarce and brief).

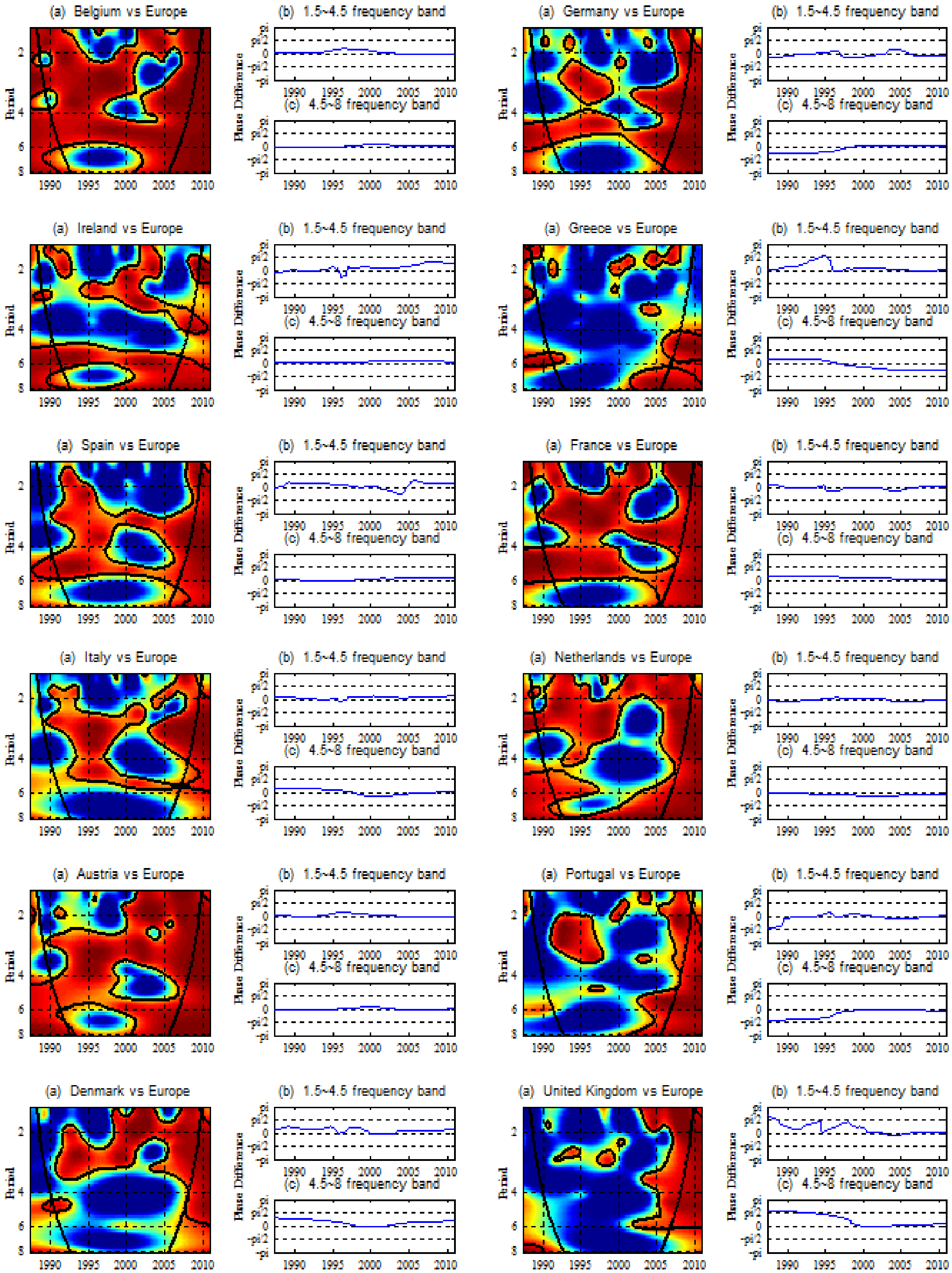

Figure 8: Wavelet coherencies and Phase-differences

We now look at the EA-10 members that overall have recorded smaller coherencies. Portugal had an episode of significant co-movement of its ESI with the EA-10 ESI between 1992 and 1998 for cycles of period between 2 and 3.5 years, but that episode turned out to be transient; it corresponds to the well-known period of high growth and apparent real convergence with the Area members-to-be, ahead of the creation of the EMU. More recently, since the mid-2000s, there seems to be significant coherencies for cycles of all periods. Finally, Greece is the EA-10 country with a clearly less synchronized economic sentiment; only for longer cycles there seems to exist some significant coherency, namely for cycles with period 6~8 years since 2002 and with period of 4~6 years since 2006.

We finally look at the wavelet coherencies of the two control countries, the UK and Denmark. The wavelet coherency between the UK and the EA-10 ESI shows that there hasn't been almost any significant coherency before 2005, and that the significant coherency estimated since then spreads out through cycles from a period of 1.5 to a period of 6 years. This pattern seems associated with the international boom that lasted until around 2007 and the bust that ensued; not enough to say that that the UK is synchronized with the rest of Europe as we saw in the previous section. The case of Denmark is different, as there are some regions of significant coherency for cycles of period between 1.5 and 3 years since the early 1990s. After a reduction of the frequency band of significant coherency in the early 2000s, after 2005 the significance expanded to cycles of higher period, reaching the 6 years period around 2007. All in all, and consistently with the results of the previous section, the wavelet coherencies suggest that there has been some EMU effect on the co-movement of economic sentiment of Denmark with respect to the EA-10, but not of the UK. Hence, we conclude that what is necessary for economic sentiment to converge with the Euro Area is not to actually integrate the EMU but merely to hard-peg the national currency to the Euro.

A fourth set of conclusions comes from the inspection of the phase-differences relative to cycles in the frequency band of 4.5~8 years. In almost all countries, those phase-differences swing — and, often, change from quadrant — at some time just before 1999, in what seems to be a structural break in the co-movement of economic sentiment in the time and frequency domain associated with the creation of the EMU. Before 1999, at cyclical oscillations within that range of periods, the EA-10 ESI led the ESIs of Germany and, with a smaller time horizon, of Belgium, Austria, the Netherlands, and Spain; in turn, the economic sentiment of France and Italy led the economic sentiment of the EA-10. After 1999, the ESI of Germany, together with those of Spain, Belgium and Ireland, led the ESI of the EA-10, while the ESIs of France and Italy gradually lost their leading role and ended the sample with a contemporaneous co-movement with the EA-10 ESI.

A fifth general set of conclusions may be drawn from the phase-differences relative to cycles in the frequency band of 1.5~4.5 years. In almost all countries there is a sudden swerve of the phase-differences at some time between 1995 and 1997; in the cases of Germany, Austria, Belgium and the Netherlands the swing is reverted only gradually and some years later, while in most of the others — France, Italy, Ireland, Greece, Denmark, Portugal, UK — its pattern is closer to a peak/trough with almost immediate reversal (truly, the case of France is somehow an intermediate one, as the trough lasts longer, about two years). The swing of the phase-differences in the first group of countries (Germany, Austria, Belgium and the Netherlands) indicates some years during which the ESI cycles of those countries (at the frequency-band of 1.5~4.5 years, recall) lead the EA-10 ESI cycles, and then since around 1999 these period cycles became simultaneous (an exception is another peak in Germany's phase-difference in 2004-06, suggesting a leading role for Germany in that episode; this is a result that we'll mention again later on). In the cases of France, Italy and Ireland, the trough around 1995 indicates a period in which those countries' ESI cycles of 1.5~4.5 years became laggards regarding the EA-10 similar cycles (later on, France's cycles became simultaneous again, with a brief exception at around 2005 that we'll mention below).

Finally, a very interesting conclusion may be drawn from the comparison of the phase-differences of France and Germany, the largest economies of the EA-10. For both frequency-bands analysed, these countries' phase-differences look very much like a mirror image of each other. In the 4.5~8 years band, until 1995 the EA-10 ESI clearly led the ESI of Germany and has been led by the ESI of France; then, between 1995 and 1999, the gradual change in the phase-differences mean that the ESIs of both countries became simultaneously synchronized with the ESI of the EA-10. In the 1.5~4.5 years frequency band, the ESI cycles of both countries were pretty much co-moving simultaneously with the EA-10 ESIs except for the peaks/troughs above identified; in short, around 1995 there is a peak in the phase-difference of Germany and a trough in the phase-difference of France, implying that the ESI cycles of Germany became leaders of the EA-10 cycles and those of France became lagers; then, the peak in Germany's phase-difference in 2004-06 indicates a leading role for Germany in that episode, which coincides with a trough in the phase-difference of France for the same cycles, indicating a leading role of the EA-10 cycle over the 1.5~4.5 years cycle of the ESI of France. Hence, we conclude that there has been some alternation in the leading role of economic sentiment in France and Germany, regarding the Euro Area, in the last decades.

5. Concluding remarks

In this paper we have used wavelet tools based on the continuous wavelet transform, to study the time and frequency-varying patterns of synchronization of business cycles in the Euro Area, using data from Economic Sentiment Indexes (ESIs). We have focused on an EA-10 aggregate and its members Austria, Belgium, France, Germany, Greece, Ireland, Italy, Spain, the Netherlands and Portugal, and have used Denmark and the UK as controls, given their contrasting exchange-rate regimes.

We contribute to the literature with a novel combination of data and methods that allows for a set of new results and conclusions, including the assessment of the possible effects of the creation of the EMU at 1999 on the co-movement of economic sentiment across the Euro Area. As regards data, the ESIs effectively pin down the overall economic mood and track quite closely the growth rate of real GDP, with the advantage of being available on a monthly periodicity for a quarter of a century. As regards methods, we first use a measure of the distance between the wavelet transforms that allows for testing the time-frequency synchronization between pairs of ESIs, and then use the wavelet coherency and the phase-differences, which give a picture of the power of the cross-wavelet at each moment of time and each frequency as well as of the lead-lag relations between ESIs at certain frequency bands.

We have found a number of empirical results, from which we highlight here only a few.

For the whole sample, economic sentiment has been significantly synchronized between a core of EA-10 countries formed by Germany, Austria, Belgium, Spain — a "German pole" —, France, Italy, Ireland — a "French pole" — and the Netherlands. The lack of synchronization (at the 5 per cent level) of the economic sentiments of Portugal, Greece and Denmark in 1987-2010 is explained by their behaviour in the period before the EMU. In fact, in 1999-2010 all EA-10 countries and Denmark have had ESIs synchronized with the aggregate EA-10. Moreover, bilateral distances have overall fallen markedly within the EA-10-plus-Denmark area after 1999. In contrast, no comparable fall in distances of the ESIs occurred after 1999 for the UK, either with regard to the EA-10 or with regard to most individual countries.

Hence, we clearly detect an EMU effect of increased synchronization of economic sentiment. The difference of results for Denmark and the UK led us to conclude that the type of exchange rate regime plays a crucial role in explaining these effects.

Germany and France seem to have had alternated roles as leaders of economic sentiment in the Euro Area. At longer cycles (4.5~8 years) the French ESI has led the EA-10 and German ESI until 1995/7, and then the ESIs turned to a simultaneous co-movement; at shorter cycles (1.5~4.5 years) the ESI cycles of both countries co-moved simultaneously with the EA-10 ESI except in 1995/7 and 2004/6, when the German economic sentiment led the EA-10 and the French ESI.

References

Aguiar-Conraria, Luís, Maria J. Soares, and N. Azevedo (2008), "Using Wavelets to Decompose the Time-Frequency Effects of Monetary Policy" *Physica A: Statistical Mechanics and its Applications*, Vol. 387, No. 12, May, pp. 2863-2878.

Aguiar-Conraria, Luís and Maria J. Soares (2011a), "Business cycle synchronization and the Euro: a wavelet analysis", *Journal of Macroeconomics*, Vol. 33, No. 3, pp. 477-489.

Aguiar-Conraria, Luís, and Maria J. Soares (2011b), "The continuous wavelet transform: a primer", NIPE - WP 16/2011.

Aguiar-Conraria, Luís, Pedro C. Magalhães and Maria J. Soares (2011), "Cycles in Politics: Wavelet Analysis of Political Time-Series", forthcoming, *American Journal of Political Science*.

Altavilla, Carlo (2004), "Do EMU Members Share the Same Business Cycle?", *Journal of Common Market Studies*, Vol. 42, No. 5, pp. 869-896.

Artis, Michael J., Massimiliano Marcellino and Tommaso Proietti (2004), "Dating the Euro Area Business Cycle", in Lucrezia Reichlin (Ed.) The Euro Area Business Cycle: Stylized facts and Measurement Issues. London, Centre for Economic Policy Research (CEPR), pp. 7-34.

Artis, Michael J., Hans-Martin Krolzig, and Juan Toro (2004), "The European Business Cycle", *Oxford Economic Papers*, Vol. 56, No. 1, pp. 1-44.

Camacho, Maximo, Gabriel Perez-Quirós, and Lorena Saiz (2006), "Are European Business Cycles close enough to be just one?", *Journal of Economics Dynamics and Control*, Vol. 30, No. 9-10, September-October, pp. 1687—1706.

Camacho, Maximo, Gabriel Perez-Quirós and Lorena Saiz (2008), "Do European Business Cycles look like one?", *Journal of Economic Dynamics & Control*, Vol. 32, No. 7, July, pp. 2165-2190.

Canova, Fabio, Matteo Ciccarelli, and Eva Ortega (2009), "Do institutional changes affect business cycles? Evidence from Europe", Banco de España Working Papers No. 0921.

Crowley, Patrick M., Douglas Maraun and David Mayes (2006) "How hard is the euro area core? An evaluation of growth cycles using wavelet analysis", Bank of Finland Research Discussion Papers No. 18.

De Haan, Jakob, Robert Inklaar and Richard Jong-a-Pin (2008), "Will Business Cycle in the Euro Area Converge? A Critical Survey of Empirical Research", *Journal of Economic Surveys*, Vol. 22, No. 2, pp. 234-273.

European Commission (2007), "The joint harmonised EU programme of business and consumer survey user guide (updated 4 July 2007)", Directorate-Generale for Economic and Financial Affairs, available at (accessed April 2010) http://ec.europa.eu/economy_finance/db_indicators/surveys/documents/userguide_en.pdf.

Furceri, Davide and Georgios Karras (2008), "Business-cycle synchronization in the EMU", *Applied Economics*, Vol. 40, No. 12, pp. 1491-1501.

Gayer, Christian (2007), "A fresh look at business cycle synchronization in the euro area", European Economy Economic Paper No. 287, September.

Gelper, Sarah and Christophe Croux (2010), "On the Construction of the European Economic Sentiment Indicator", *Oxford Bulletin of Economics and Statistics*, Vol. 72, No. 1, 47-61.

Giannone, Domenico, Michele Lenza and Lucrezia Reichlin (2009), "Business Cycles in the Euro Area", European Central Bank Working Paper No. 1010, February.

Hallett, Andrew H. and Christian Richter (2008), "Have the Eurozone economies converged on a common European cycle?", *International Economics and Economic Policy*, Vol. 5, No. 1-2, July, 71-101.

Hallett, Andrew H. and Christian Richter (2006), "Measuring the Degree of Convergence among European Business Cycles", *Computational Economics*, Vol. 27, No. 2-3, 229-259.

Hallett, Andrew H. and Christian Richter (2004a), "Spectral Analysis as a Tool for Financial Policy: An Analysis of the Short-End of the British Term Structure", *Computational Economics*, Vol. 23, No. 3, 271-288.

Hallett, Andrew H. and Christian Richter (2004b), "A Time-Frequency Analysis of the Coherences of the US Business Cycle and the European Business Cycle", CEPR Discussion Paper No. 4751, November.

Koopman, Siem J. and João V. E. Azevedo (2008), "Measuring Synchronization and Convergence of Business Cycles for the Euro area, UK and US", *Oxford Bulletin of Economics and Statistics*, Vol. 70, No. 1, 23-51.

Rua, António (2010), "Measuring comovement in the time—frequency space", *Journal of Macroeconomics*, Vol. 32, No. 2, 685—691.

Wozniak, Przemyslaw and Woivciech Paczynski (2007), "Business Cycle Coherence between the Euro Area and the EU New Member States: a Time-Frequency Analysis", CASE—Center for Social and Economic Research, Manuscript, 3 July.